XXXV.—*On the Composition of Chalk Rocks and Chalk Marl by invisible Organic Bodies: from the Observations of Dr. Ehrenberg*[*]. By Thomas Weaver, Esq., F.R.S., F.G.S., M.R.I.A., &c. &c.[†]

The remarkable discoveries effected, and the new light thrown on geology by the indefatigable researches of Dr. Ehrenberg, during several years past, through the medium of the microscope, particularly in respect of the Infusoria and Polythalamia tribes, highly instructive and interesting as they must be to all naturalists, are especially so to the geologist, since they open to him a large field of inquiry, eminently deserving of cultivation. To draw attention to this subject, which involves no less than an investigation as to what extent minute organic bodies, invisible to the naked eye, may have contributed to the production of all limestone formations, whether of an origin posterior or anterior to the epoch of the chalk, descending thus in the series to the primary limestones, it appeared to me that a sketch taken from a portion of the labours of Dr. Ehrenberg might be not only useful, but especially acceptable to such geologists as may not be conversant with the language of the original. I propose then, in the first instance, to advert briefly to the earlier researches of Dr. Ehrenberg concerning the Coral tribes in general, and those of the Red Sea in particular[‡]; and in the second, to present such extracts from the Memoir, the title of which stands at the head of this paper[§], as may answer the purpose of a general view.

At the instigation of the Royal Academy of Sciences of Berlin[||], Dr. Ehrenberg and his friend, the late Dr. Hemprich, visited the Red Sea during a period of eighteen months, namely, nine months from the year 1823 to 1824, and an equal number in 1825, having been nearly twelve months of the time on board ship, in which interval they passed over nearly the whole extent of that sea, saw many of its islands and coral banks, and landed with a view to special examination on forty-eight different points of the two coasts; but the whole number of islands and special points of the coast seen by them amounts to about 150, independently of the long coast of Sinai in Arabia, which they examined in continuity. In these laborious efforts, attended with extreme danger, they collected 110 species of Coral animals, being nearly three times as many as had been found or described by all former observers, namely, by Shaw, Forskål and Savigny, and later by Rüppel.

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[*] Communicated by the Author.

[†] With an Appendix touching the researches of M. Alcide d'Orbigny.

[‡] See in the Abhand. der König. Acad. d. Wissenschaften zu Berlin for the year 1832:—

1. Contributions to the physiological knowledge of the Coral animals in general, and in particular of those of the Red Sea, with an attempt to classify them according to their physiological distinctions; read 3rd March, 1831, with additions printed 1st Dec. 1833, pp. 225–380.

2. On the Nature and Structure of the Coral Banks of the Red Sea, read 22nd March 1832; revised and printed in Feb. 1834, pp. 381–432.

[§] *Ueber die Bildung der Kreidefelsen und des Kreidemergels durch unsichtbare Organismen*, in the Transactions of the Royal Academy of Sciences of Berlin, for the year 1838, read 20th Dec. 1838, and 18th Feb. 1839, pp. 59–149.

[||] See the Report read to the Academy by M. Alr. von Humboldt on the Travels of Doctors Ehrenberg and Hemprich through Egypt, Dongola, Syria, Arabia, and the Eastern declivity of the highlands of Abyssinia, in the years 1820–1825, conveying a clear idea of the arduous and extraordinary labours of those gentlemen in all branches of Natural History: Berlin, 1826. Dr. Hemprich fell a sacrifice to his exertions in Abyssinia, on the 30th of June, 1825.

To determine the subjects of that collection with the greater precision, it became necessary to undertake a review of the whole class of the Coral animals, and the more so as Dr. Ehrenberg found that his own observations were frequently in collision with the systematic distinctions that have prevailed up to the present time. In this review the author has especially compared the four most recent extensive systems, namely, of Schweigger in 1820, Rapp in 1829, Cuvier in 1830, and Blainville likewise in 1830, which may be said to embody the judgment of the present generation upon the labours of earlier periods, and to comprise the sum of existing knowledge in this department of natural history. He has in particular turned his attention to the work of Blainville *, since it contains the greatest number of new details, having been enriched by the latest manuscript observations and drawings of Quoy and Gaimard, the result of their second voyage round the world with Capt. D'Urville. In these newer works, the labours of Lamarck having been critically employed, the author was relieved from the necessity of noticing them in a special manner.

The attempt to reconcile the observed discrepancies led the author to separate the Coral animals into two organic natural groups, which are well marked and distinct from each other, and which he named *Anthozoa* (Flower-animals) and *Bryozoa* (Moss-animals). In the course of these researches the author found that the whole group of the Anthozoa, which consist of the proper (single-mouthed) coral animals, and which had been gradually distributed under more than 158 generic names, including even heterogeneous animals and plants, might, according to his own observations of their correspondence in affinity and relations of structure and development, be reduced to eighty-six genera, but which number might perhaps be still further diminished, as a few genera might be classed as sub-genera. The Anthozoa he has divided into two orders, *Zoocorallia* (Animal-corals) and *Phytocorallia* (Plant-corals). In the Memoir is given a systematic description of the Orders, Tribes, Families, Genera and Species of the Anthozoa, while further details are reserved for the author's work, entitled, *Symbolæ Physicæ*. The subjoined Table will show the general arrangement, extending to the genera.

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* *Dictionnaire des Sciences Naturelles,* 1830.

ANTHOZOA.

Ore ventriculoque distinctis, tubo cibario anoque discreto nullis, corpore intus radiatim lamelloso. (Vibratio nulla, gemmæ et spontanea divisio frequentissimæ.)

ORDO I.—ZOOCORALLIA.

Corpore aut omnino molli, aut Cephalopodum more intus lapidem generante (secernente nec excernente) hinc sæpe omnino libera et, præter formam, animalium characteres omnes perfectius servantia.

			Species.			
		Of the Red Sea.				
		Unproved.	Observed by himself.	Total living.	Fossil Genera.	Genera.
TRIBUS I. Zoocorallia Polyactinia.	Familia I. ACTININA. Genera 9. Species living . 50. In the Red Sea 23.	...	16	29	...	1. Actinia.
		...	1	1	...	2. Metridium.
		...	1	1	...	3. Megalactis.
		1?	...	1?	...	4. Thalassianthus.
		...	1	10	...	5. Cribrina.
		...	1	3	...	6. Actinodendron.
		...	1	1	...	7. Epicladia.
		...	1	1	...	8. Heterodactyla.
		...	...	3	...	9. Lucernaria.
	Fam. II. ZOANTHINA. Genera 4. Fossil 2. Species living . 12. In the Red Sea 7.	...	2	3	...	10. Hughea.
		1	...	2	...	11. Zoanthus.
		1	1	4	...	12. Mammillifera.
		...	2	3	...	13. Palythoa.
		...	...	...	F.	Siphonia.
		...	...	...	F.	Lymnorea.
	Fam. III. FUNGINA. Genera 6. Fossil 5. Species living . 12. In the Red Sea 3.	...	1	3	F.	14. Fungia.
		...	1	5	...	15. Haliglossa.
		...	...	3	...	16. Polyphyllia.
		...	...	...	F.	17. Cyclolithas.
		1 ?	...		F.	18. Turbinalia.
		...	...	...	F.	19. Trochopsis.
		...	...	...	F.	Diploctenium.

			Species.			Fossil Genera.	Genera.
			Of the Red Sea.		Total living.		
			Unproved.	Observed by himself.			
TRIBUS II.	Zoocorallia Octactinia.	Fam. IV. XENINA. Genera 3. Species living . 7. In the Red Sea 6.	...	3	3	...	20. Xenia.
			...	3	3	...	21. Anthelia.
			...	...	1	...	22. Rhizoxenia.
		Fam. V. TUBIPORINA. Genus 1. Species living . 3. In the Red Sea 1.	...	1	3	...	23. Tubipora.
		Fam. VI. HALCYONINA. Genera 6. Species living 28. In the Red Sea 13.	...	1	1	...	24. Halcyonium.
			...	5	12	...	25. Lobularia.
			...	2	2	...	26. Ammothea.
			...	2	4	...	27. Nephthya.
			...	3	8	...	28. Sympodium.
			...	...	1	...	29. Cliona.
		Fam. VII. PENNATULINA. (*a*) HALISCEPTRA. Genera 4. Species living . 7. In the Red Sea 0.	...	...	4	...	30. Veretillum.
			...	...	1	...	31. Pavonaria.
			...	...	1	...	32. Umbellularia.
			...	...	1	...	33. Scirpearia.
		(β) HALIPTERIA. Genera 3. Fossil 1. Species living . 10. In the Red Sea 0.	...	...	2	...	34. Renilla.
			...	...	3	F.?	35. Virgularia.
			...	...	5	...	36. Pennatula.
TRIBUS III.	Zoocorallia Oligactinia.	Fam. VIII. HYDRINA. Genera 2. Species living . 6. In the Red Sea 0.	...	...	4	...	37. Hydra.
			...	...	2	...	38. Coryna.
		Fam. IX. TUBULARINA. Genera 4. Species living . 12. In the Red Sea 0.	...	...	4	...	39. Syncoryna.
			...	...	3	...	40. Tubularia.
			...	...	4	...	41. Eudendrium.
			...	...	1	...	42. Pennaria.
		Fam. X. SERTULARINA. Genus 1. Species living . 4. In the Red Sea 1.	1 ?	...	4	...	43. Sertularia.
		ZOOCORALLIA...	5	49	151	8	

ORDO II.—PHYTOCORALLIA.

Corpore aut lapideam aut corneam materiam adglutinantem secernente, ac dorso (solea) excernente ejusque ope semper adnato (Ostrearum more).

			Species.				
			Of the Red Sea.				
			Unproved.	Observed by himself.	Total living.	Fossil Genera.	Genera.
TRIBUS IV.	Phytocorallia Polyactinia.	Familia XI. OCELLINA. Genera 14. Fossil 12. Species living 41. In the Red Sea 7.	...	...	2	...	44. Desmophyllum.
			...	...	3	...	45. Cyathina.
			...	1	1	F.	46. Stephanocora.
			...	...	3	F.	47. Monomyces.
			...	1	9	F.	48. Oculina.
			...	...	4	F.	49. Turbinaria.
			...	3	8	F.	50. Explanaria.
			...	...	6	F.	51. Cladocora.
			...	...	...	F.	52. Columnaria.
			...	1	1	F.	53. Strombodes.
			...	...	...	F.	54. Cyathophyllum.
			...	...	...	F.	55. Pterorrhiza.
			...	1	4	F.	56. Anthophyllum.
			...	...	...	F.	57. Stylina.
		Fam. XII. DÆDALINA. (*a*) ASTRÆINA. Genera 4. Fossil 3. Species living 28. In the Red Sea 15.	1	2	7	...	58. Caryophyllia.
			...	4	7	F.	59. Favia.
			...	8	14	F.	60. Astræa.
			...	...	...	F.	61. Favosites.
		(*β*) MÆANDRINA. Genera 7. Fossil 6. Species living 28. In the Red Sea 5.	...	2	7	F.	62. Mæandrina.
			...	2	12	F.	63. Manicina.
			...	...	1	...	64. Merulina.
			...	1	4	F.	65. Pavonia.
			...	...	2	F.	66. Agaricia.
			...	...	2	F.	67. Polyastra.
			...	...	...	F.	68. Monticularia.
TRIBUS V.	Phytocorallia Dodecactinia.	Fam. XIII. MADREPORINA. Genera 3. Fossil 3. Species living 41. In the Red Sea 24.	...	7	21	...	69. Heteropora.
			...	17	20	F.	70. Madrepora.
			...	...	...	F.	71. Catenipora.
			...	...	...	...	Pleurodictyum.
		Fam. XIV. MILLEPORINA. Genera 4. Fossil 2. Species living 23. In the Red Sea 11.	...	...	...	F.	72. Calamopora.
			...	4	6	...	73. Seriatopora.
			1	2	7	F.	74. Millepora.
			...	3	10	...	75. Pocillopora.
TRIBUS VI.	Phytocorallia Octactinia.	Fam. XV. ISIDEA. Genera 4. Species living 10. In the Red Sea 1.	...	...	1	...	76. Corallium.
			...	...	4	...	77. Melitæa.
			...	1	3	...	78. Mopsea.
			...	...	2	...	79. Isis.
		Fam. XVI. GORGONINA. Genera 6. Fossil 1. Species living 63. In the Red Sea 3.	1?	...	3	...	80. Prymnoa.
			1?	...	10	...	81. Muricea.
			...	...	23	...	82. Eunicea.
			1?	...	4	...	83. Plexaura.
			...	...	12	F.?	84. Gorgonia.
			...	...	11	...	85. Pterogorgia.
TRIBUS VII.	Phytocorallia Oligactinia.	Fam. XVII. ALLOPORINA. Genus 1. Species living 1. In the Red Sea 0.	...	...	1	...	86. Allopora.
		PHYTOCORALLIA	5	61	235	27	
		ZOOCORALLIA	5	49	151	8	
		ANTHOZOA	10	110	386	35	
		Of the Red Sea	120				

In the preceding Table we see that of the forty-three genera of Zoocorallia, there are eight which are found fossil; the living species amount to 151, of which fifty-four exist in the Red Sea, and forty-nine of these have been observed by the author, five remaining unproved. Of the forty-three genera of Phytocorallia there are twenty-seven which are found fossil; the living species amount to 235, of which sixty-six exist in the Red Sea, and sixty-one of these have been observed by the author, five remaining unproved. The general result is, that out of eighty-six genera of Anthozoa, thirty-five occur in the fossil state; and that of 386 known living species of Anthozoa, 120 exist in the Red Sea, of which 110 species were observed by the author. The same Table also shows that of the seventeen families of known Coral animals, thirteen exist in the Red Sea, while four are wholly wanting, namely, those of Pennatulina, Hydrina, Tubularina and Alloporina. The total number of known living species comprised in each family is also given, as well as the relative number actually existing in the Red Sea.

The 120 species of Anthozoa existing in the Red Sea thus constitute nearly one third of the whole number of living species, and being comprised in forty-four genera, the latter rather exceed one half of the number of known living genera.

Of the known living Corals there are eight genera peculiar to the Red Sea, namely, *Megalactis*, *Thalassianthus?*, *Epicladia*, *Heterodactyla*, *Anthelia*, *Ammothea*, *Stephanocora* and *Strombodes*. It appears also that eighty-eight species are peculiar to it, not having been hitherto observed anywhere else.

Among the genera of the Red Sea that of *Strombodes* excites peculiar interest, having previously been found only in the fossil state. It affords a key to the structure of the remarkable Cyathophylla, differing from the view hitherto entertained, and rendering it quite clear that the internal central star of the encased forms is not a young one, but the oldest or mother star, which is often surrounded by broad radiated mantle-folds productive of buds.

It appears probable that the Red Sea and the part of the Mediterranean so nearly adjoining on the Libyan coast, possess only two forms out of the 120 species in common, namely, *Actinia Tapetum* and *A. Mesembryanthemum.*

Of the Bryozoa group, Dr. Ehrenberg gave in the same memoir, contained in the volume of the Transactions for 1832, only the more general results of his investigations, without entering into detail; but the subject is resumed in his later memoir, inserted in the volume for 1838, in which he has presented a tabular view of the Bryozoa, distributed into Orders, Families and Genera, with their characteristics. According to this view the Bryozoa comprise four Orders, *Polythalamia*, *Gymnocoræ*, *Thallopodia* and *Scleropodia*; the Polythalamia being divided into *Monosomatia* (single-bodied), consisting of fifty-six genera, and *Polysomatia* (many-bodied or polyparian), composed of twenty-two genera, forming altogether seventy-eight genera of Polythalamia. The following Table exhibits the general arrangement.

Bryozoa.

Animalia asphycta, tubo cibario simplici, sacciformi aut tubuliformi, vera corporis articulatione nulla aut sensim numerosiore, corporis forma gemmis aut novis articulis accedentibus sensim aucta, hinc indefinita, nunquam sponte dividua, omnia et singula verisimiliter periodice ovipara, ideoque hermaphrodita.

Ordo I.—Polythalamia.

Libere vagantia et loricata.

Monosomatia.

Familia I. Miliolina.
  Genera 2. ? Miliola, ? Gromia.
Familia II. Nodosarina.
  Gen. 11. Glandulina, Mucronina, Nodosaria, Orthocerina, Dentalina, Lingulina, Frondicularia, Rimulina, Vaginulina, Planularia, Marginulina.
Familia III. Textularina.
  Gen. 6. Bigenerina, ? Dimorphina, Textularia, Grammostomum (*Vulvularia*), Polymorphina, Virgulina.
Familia IV. Uvellina.
  Gen. 11. Guttulina (et *Globulina*), Uvigerina, Bulimina, Valvulina, Rosalina, Clavulina, Globigerina, Pyrulina, Sphæroidina.
Familia V. Rotalina.
  Gen. 22. Operculina, Soldania, Planorbulina, Rotalia, Trochulina, ? Spirulina, Calcarina, Pleurotrema, Planulina, Discorbis, Omphalophacus, ? Gyroidina, Truncatulina, Lenticulina, Nonionina, Cristellaria, Siderolina, Dendritina, Robulina, Anomalina, Saracenaria, Cassidulina.
Familia VI. Plicatilia.
  Gen. 6. Biloculina, Spiroloculina, Triloculina, Articulina, Quinqueloculina, Adelosina.

Polysomatia.

Familia VII. Asterodiscina.
  Gen. 5. Asterodiscus, Lunulites, Orbitulites, Cupularia, Flustrella.
Familia VIII. Soritina.
  Gen. 2. Sorites, Amphisorus.
Familia IX. Frumentarina.
  Gen. 3. ? Dactylopora, ? Ovulites, ? Polytripe.
Familia X. Helicosorina.
  Gen. 5. Peneroplis, Pavonina, Vertebralina, Orbiculina, ? Heterostegina.

Familia XI. HELICOTROCHINÆ.
Gen. 3. Polystomella, ? Amphistegina, ? Geoponus.
Familia XII. ALVEOLINEA.
Gen. 2. Melonia, Alveolina.
Familia XIII. FABULARINA.
Gen. 2. Fabularia, Coscinospira.

ORDO II.—GYMNOCORÆ.

Libere vagantes, nudæ.

Familia I. CRISTATELLINA.
Gen. 2. Cristatella, Zoobotryon.

ORDO III.—THALLOPODIA.

Stolonibus thallove membranaceo affixa, incrustantia nec adnata, sed loricata.

Familia I. HALCYONELLEA.
Gen. 8. Halcyonella, Vesicularia, Bowerbankia, Farrella (= *Lagenella*) *, Valkeria, Stephanidium, n. G., Dynamene, Halodactylus (= *Alcyonidium*).
Familia II. CORNULARINA.
Gen. 1. ? Cornularia.
Familia III. ESCHARINA.
Gen. 5. Eschara, Melicertina (= *Melicerita*) †, Crisia, Acamarchis, Notamia.
Familia IV. CELLEPORINA.
Gen. 5. Cellepora, Flustra, Membranipora, Briolophus, n. G., Apsendesia.
Familia V. AULOPORINA.
Gen. 1. Tubulipora.

ORDO IV.—SCLEROPODIA.

Stolonibus destituta, excreto fulcro axique anorganicis firmiter affixa eisque fruticulosa.

Familia I. MYRIOPORINA.
Gen. 9. Hornera, Idmonea, Retipora, Distichopora, Myriopora, Tilesia, Cricopora, Ceriopora, Spiropora.
Familia II. ? ANTIPATHINA.
Gen. 1. Antipathes.

"The two last orders, the Thallopodia and Scleropodia," the author observes, "are considerably richer in forms, and it would be very easy by an uncritical compilation to enlarge greatly the number of names; but such confusion has been produced in names by Lamouroux and later writers, the same body being often designated by many new names, that I shall not venture to extend my judgment further at present. What has been advanced will suffice to show clearly the position of the Polythalamia, such as it appears to me, in the animal kingdom."

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* The name *Lagenella* was appropriated to an infusorial form in 1832.

† *Melicerta* is already employed among the Radiaria, *Melicertum* with the Acalepha, *Melicerita* is not correct in language.

Perhaps hereafter it may be advisable to substitute *Textilaria* for Textularia, *Polystomatium* for Polystomella, *Cyclodiscus* for Discorbis, &c.

On Chalk and Chalk Marl.

The memoir on the chalk and chalk marl is distributed under the following heads:—

1. Historical Introduction, pp. 59—68.

2. New method of observing, pp. 68—70.

3. On calcareous-shelled organisms, invisible to the naked eye, as the principal constituents of writing chalk, pp. 70—74.

4. On Chalk Marl and its relations to Chalk, and to the Flints of the Chalk, pp. 74—87.

5. On the compact limestone of Upper Egypt and Arabia, as formed by the Polythalamian calcareous animalcules of the White Chalk of Europe, pp. 87—90.

6. On the principal organic calcareous forms which constitute all chalk, and the local differences, pp. 90—95.

7. Preliminary view of new researches respecting living Polythalamia, and their relation to the formation of the sand of Sea Downs, pp. 96—106.

8. Application of the preceding observations to the systematic distinctions of Polythalamia, with a tabular view of the Bryozoa, according to their orders, families and genera, with their characteristics, pp. 107—121.

(N.B. Of this tabular view I have given a transcript above.)

9. On the geographical distribution of living Polythalamia on the African and Asiatic coasts of the Mediterranean, and in the Red Sea, with a tabular view of the genera and species, pp. 121—127.

10. A concise Diagnosis of the new families, genera and species,

   1. Of the siliceous Infusoria of the chalk marl, containing thirty-one new species, of which seventeen species belong to five new genera, and fourteen species to five former-known genera, pp. 128—130.
   2. Of the calcareous-shelled Polythalamian animalcules of the chalk and sea sand, sixty-seven new species, beside two new species from the Jura (Oolite) limestone, pp. 130—135.

11. A summary view of the conclusions drawn from the preceding expositions, pp. 135—139.

12. Explanation of the Plates, pp. 140—147.

13. A tabular view of the organic bodies invisible to the naked eye, which form the chief constituents of chalk, chalk marl, the compact limestone of Egypt and Arabia, and the nummulitic limestone of the Pyramids of Geza or Gyzeh.

The reader being thus put in possession of the general scope of the work, I now proceed to exhibit in full the conclusions to which the author has been led (as indicated under the head of No. 11), to which I shall subjoin further extracts taken from different portions of the Memoir, for the purpose of general illustration.

Conclusions.

1. Many, and probably all, *White Chalk Rocks* are the produce of microscopic coral-animalcules, which are mostly quite invisible to the naked eye, possessing calcareous shells of $\frac{1}{24}$ to $\frac{1}{288}$ line in magnitude, and of which much more than one million are well preserved in each cubic inch, that is, much more than ten millions in one pound of chalk *.

2. The *Chalk Marls* of the Mediterranean Basin are the produce of microscopic Infusoria possessing siliceous shells or cases, mostly quite invisible to the naked eye, intermingled with a small proportion of the calcareous animalcules of the chalk.

3. The peculiar state of aggregation in *White Chalk* does not arise from a precipitate of lime previously held in solution in the water of the sea, nor is it the result of the accumulation of the small animalcules, but it proceeds from a disintegration of the assembled microscopic organisms into much minuter inorganic calcareous particles; the reunion of which into regular, elliptical, granular laminæ, is caused by a peculiar crystalloid process, which may be compared to crystallization, but is of a coarser nature, and essentially different from it. The best writing chalk is that in which this process has been developed to the greatest extent.

4. The compact limestone rocks also which bound the Nile in the whole of Upper Egypt and extend far into the Sahara or Desert, being neither white nor of a staining quality, as well as the West Asiatic compact limestone rocks in the north of Arabia, are, in the mass, composed of the coral animalcules of the European chalk. This affords a new insight into the ancient history of the formation of Libya from Syene to the

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* It is to be understood that I speak only of such Polythalamia as are well preserved, wholly disregarding their fragments. Of the well-preserved there are contained in one fourth part of a cubic line, or in one twelfth of a grain of chalk, frequently 150 to 200 in number, equal to 600–800 in each cubic line, or 1800–2400 in each grain, and from 1,036,000 to 1,382,400 in each cubic inch; and hence in one pound of chalk the number far exceeds ten millions.

The larger Polythalamia and Bryozoa of the chalk are best obtained from the sediment produced by brushing the chalk under water; the entirely microscopic forms remain long suspended in water.

Atlas, and of Arabia from Sinai to Lebanon, thus opening a large field to organic distribution.

5. Many of the chalk-like formations bordering on the Mediterranean in Sicily, Barbary and Greece, really belong to the period of the European chalk formation, as proved by their organic contents, although commonly held to be different from the chalk, and considered as tertiary *.

6. The chalk beds of the South of Europe, around the basin of the Mediterranean, are distinguished from those of the north and east of Europe by numerous well-preserved chalk animalcules, and less numerous inorganic laminæ; while in the north and east of Europe these relations are reversed †.

7. In the South of Europe the beds of marl which alternate with the chalk consist of siliceous shells of Infusoria, and flints are wanting; while in the North of Europe beds of flint alternate with the chalk, and marls with Infusoria are wanting. This exchange of character tends to explain the peculiar relation of flint to chalk, indicating that the pulverulent siliceous particles of Infusoria have been converted into compact nodules of flint.

8. It has been lately remarked that the chalk which contains flints is deficient in numerous siliceous Infusoria, when compared with the Bilin slaty Tripel or polishing slate (*Polirschiefer*) containing semi-opal; but this deficiency now disappears, and a rich substitute takes its place, the Infusoria in the North of Europe having been employed in the formation of flints; while in the south, remaining unchanged, they are preserved in the Infusoria marls.

9. The chalk animalcules resemble most those of the sea-sand and the Miliolites, which, up to the present day, have been ranged among the Mollusks with the Cephalopods; but neither of these are either Cephalopods or Mollusks, nor even Infusoria (as asserted by a late observer); but they are Bryozoa, animals of Moss-corals, which are most nearly related to Flustra and Eschara.

10. The sea downs of some, and probably of most coasts, are still in course of formation by living Bryozoa, which, though very small, resembling grains of sand, are yet, for the most part, larger than the chalk animalcules, and a large pro-

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* In Sicily, however, there occur many breccias of chalk, which have suffered a subsequent change, and may be referred to the tertiary epoch.

† Thus in the white and yellow soft writing chalk of the North of Europe the inorganic crystalloid portions sometimes equal or rather exceed in mass the organic remains; but in the South of Europe, in Sicily, these organisms with their fragments are greatly predominant, consisting, as it appears, exclusively of well-preserved Polythalamia.

portion of the sand of the Libyan Desert has been proved to consist of such grains. It is only in Nubia above Syene that the desert sand becomes a pure detritus of granite*.

11. In the various countries of the earth in which occur white and earthy, as well as coloured and compact rocks, composed of microscopic calcareous animalcules, the genera and species of these animalcules present so striking an agreement with those of the white chalk of Rügen, that they may well be deemed characteristic of one and the same period of geological formation. It cannot be asserted for a certainty that the same forms have been observed any where else†.

12. In the beds subjacent to and more ancient than the chalk, namely, in those of the Oolite or Jura limestone formation, we have also clear evidence of the existence of other microscopic Polythalamia. These, however, are such as have not hitherto been found anywhere in the chalk.

13. The early assertion that *all* limestone was the produce of animals‡, though resting on no sufficient foundation, and therefore justly held in slight regard by modern geologists, yet now deserves every attention, since it clearly appears that a limestone formation widely extended on the surface of the earth is composed of microscopic animals, visibly converted in a gradual manner into inorganic chalk and compact limestone. If similar phænomena appear also in the Jura limestone formation, and should become still further confirmed, these considerations (combined with the long-known existence of coarser corals and shells in both formations) tend to show how necessary it is, when examining the composition of any considerable portion of the solid mass of the earth, to strengthen our natural senses by artificial means, in order to obtain a distinct knowledge of the extent to which organic life may have contributed to its production.

14. The extreme minuteness of the chalk animalcules is strikingly proved by this, that even in the finest levigated whiting multitudes of them are still present, and may be applied without suffering change to the most varied technical purposes. Thus in the chalk coating given to painted chambers, paper, or even glazed visiting-cards (when not coated with white lead

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* On these very interesting and not easily developed relations, I hope, at a future day, to be able to make a more special communication.

† If I have applied the same name in some cases both to animalcules of the chalk and to forms existing in the present sea-sand, or in recent fossil beds, it has arisen partly from my being unacquainted with the original forms of the latter, and partly from my desire not to create unnecessary perplexity by the adoption of new names. It should be observed that they are distinguished by marks of interrogation. All those which I could really compare were different.

‡ By Linnæus in 1745 and 1748, and Buffon in 1749.

alone), may be seen a pretty mosaic of well-preserved, moss-coral animalcules, but which are invisible to the naked eye. And thus our natural vision receives from such a surface the impression of the purest white, little deeming that it contains the bodies of millions of self-existing beings, of varied and beautiful forms, more or less closely crowded together (as in Plate IV., where the subjects are magnified 300 times).

Explanation of the Plates and Tabular View.

The Memoir is accompanied by four Plates*, presented with the view of facilitating a comparison between the organic relations of minute fossil bodies invisible to the naked eye, and those of still living bodies visible to the naked eye.

Thus the first three Plates exhibit recent small bodies naturally visible, with which the naturally invisible forms of the fourth Plate may be readily associated.

The first three Plates serve also to elucidate the true nature of the Polythalamia (hitherto mistaken), showing their greater affinity to the Bryozoa (Flustra) than to all other animal forms, and in particular the great difference there is between them and Cephalopods and Infusoria. They represent partly the unfolded, soft, external parts of living subjects, and partly dead, naked bodies, artificially divested of their calcareous shell, and not hitherto figured.

Lastly, these first three Plates serve to convey a view, according to some of their principal divisions, of the structure of the whole group of forms occurring in Polythalamia, and in particular to illustrate their frequent assemblage in families, or Polyparies, as they are termed. Plate I. contains simple forms; Plates II. and III. composite or family forms, Polyparies; of which Plate II. contains family forms assembled in single rows, and Plate III. family forms arranged in many rows.

If, as already observed, we examine a wall or paper whitened with finely levigated chalk, or a glazed visiting-card not coated with white lead alone, but also with chalk, they would appear, when magnified 300 times, more or less rich in subjects, as represented in Plate IV.

Plate I. contains *simple recent Polythalamia* from the sea-sand of Rimini. Fig. 1. *Rotalia Beccarii*; the shell only was known, but the figures show also the form of the animal when deprived of its shell by an acid, the form of both being the same. Fig. 2. *Marginulina Raphanus* (*Nodosaria Raphanus*, *Nautilus Raphanus priorum*), also very common at Rimini and other Italian coasts, and which had hitherto been erroneously ranked with Orthocera.

Plate II. contains *Polyparies of recent Polythalamia assem-*

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* These plates do not accompany Mr. Weaver's paper.

bled in single rows, from the Red Sea and the Mediterranean. The two subjects represented in this Plate were collected by me in the year 1823, and it is peculiarly interesting, through my newly-discovered method of observing*, to have been able to see in several divisions of the internal body the remains of the siliceous Infusoria, of which they had made a repast fifteen years before. Fig. 1. *Peneroplis planatus*, d'Orbigny, *Nautilus planatus* of Fichtel and Moll, from the Red Sea. The shells of this animalcule were hitherto only known, but the soft organic animal form which they inclose is here also represented. Fig. 2. *Coscinospira Hemprichii*, a form from the Red Sea, also found in the Libyan part of the Mediterranean, and which was formerly erroneously placed adjoining the *Spirula* of the Cephalopods, and more recently as connected, through *Lituolites nautiloides*, with *Spirolina*.

Plate III. contains *Polyparies of recent Polythalamia assembled in many rows*. This Plate contains the only living animalcule of the Polythalamia group, hitherto so far observed as to admit of its classification. The three forms given in this Plate, constructed of many rows of animalcules, may be distinctly associated with the Flustra and Eschara of the Bryozoa, to which, through the well-known *Lunulites* and *Orbitulites* (hitherto ranked with coral animals), they approximate in a convincing manner. Fig. 1. *Orbiculus numismalis*, from the sea-sand of the Antilles Isles. Fig. 2. *Sorites orbiculus* = *Nautilus orbiculus*, Forskål, *Nummulina* (*Assilina*) *nitida*, d'Orbigny,? from the Red Sea. The same species lives also in the Mediterranean. In a part magnified 300 times we see the animalcule with eight feelers protruding from its cell. In some of the cells may be seen distinct shells of siliceous Infusoria; in others appear oviform globules. Fig. 3. *Amphisorus Hemprichii* closely resembles the *Sorites*; but it has cells on both sides bearing single animalcules, and hence the discs are twice as thick as in *Sorites*. If we compare *Sorites* with *Flustra*, we may place *Amphisorus* by the side of *Eschara*, but, being both free moving bodies, they are different from them.

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* The new method of observing is the following:—Place a drop of water upon a lamina of mica, and put into it of scraped chalk as much as will cover the fine point of a knife, spreading it out and leaving it to rest a few seconds; then withdraw the finest particles which are suspended in the water, together with most of the water, and let the remainder become perfectly dry. Cover this remainder so spread out with *Canadian balsam*, the turpentine of the *Pinus* (*Abies*) *balsamea*, and hold it over a lamp until it becomes slightly fluid without froth. A preparation thus made seldom fails, and when magnified 300 times in diameter we see that the mass of the chalk is chiefly composed of minute well-preserved organisms. In this preparation all the cells of the Polythalamia appear at first black with a white central spot, which is caused by the air contained in the cells, which, as is well known, appear under water as annular black bodies; but by degrees the balsam penetrates into all the single cells, the black rings of the air vesicles disappear, and we recognize all the small cells of the Polythalamian animals, often presenting a very pretty appearance.

Plate IV. contains the *invisible animalcules of the chalk and chalk marl*, displayed in twelve specimens of rock; 1 to 9 being portions from the chalk, and 10 to 12 from the chalk marl, magnified 300 times. In these specimens the calcareous Polythalamia amount to sixteen species, and the siliceous Infusoria to twelve species, with siliceous spicula of sponges. The twelve localities from which these specimens of the rock masses were derived are the following:—No. 1 to 5, *writing chalk*; namely, 1. from Puszkary, in Poland, opposite Grodno, from the shore of the Memel; 2. from Jütland, in Denmark; 3. from the island of Rügen in Pomerania; 4. from Gravesend, on the Thames; 5. from Meudon, near Paris; *firmer* writing chalk, No. 6, from Cattolica in Sicily; *compact*, *not writing* chalk, No. 7, from the Mokattum hills near Cairo; and No. 8, from the Catacombs of Thebes in Upper Egypt; *compact gray limestone*, No. 9, from the mountain mass of Hamam Faraūn in Sinai, Arabia; *chalk marl*, No. 10, from Oran in Africa; No. 11, from Caltasinetta in Sicily; No. 12, from Greece.

In the *general table* indicated above, under the head of No. 13 of the contents of the memoir, a list is given of the principal forms of the invisible organic bodies which constitute the rocks from which the twelve above-mentioned specimens were taken, as well as the chalk of Brighton, the chalk marl of Zante in the Ionian Islands, and the nummulite limestone of the Pyramids of Geza in Egypt. From this it results that the principal forms in these rocks consist of twenty-five species of calcareous-shelled Polythalamia, thirty-nine species of siliceous-shelled Infusoria, seven species of soft-shelled Infusoria of the flints, and five species of siliceous plants.

The twenty-five species of calcareous-shelled Polythalamia, belonging to eight genera, are the following:—

Flustrella *concentrica*; Globigerina *bulloides*?, G. *helicina*?; Planulina *sicula*, P. **turgida*; Robulina *cretacea*; Rosalina **foveolata*, R. *globularis*?, R. **lævigata*, R. *pertusa*; Rotalia **globulosa*, R. *ocellata*, R. *ornata*, R. *perforata*, R. *scabra*, R. *stigma*; Textularia *aciculata*?, T. **aspera*, T. *brevis*, T. **dilatata*, T. **globulosa*, T. *perforata*, T. *spinosa*, T. **striata*; Turbinulina *italica*? Quinqueloculina? from Benisuef, is doubtful. N.B. *Textularia globulosa*, when in fragments, is not easily distinguished from *Rotalia globulosa*; and in like manner the fragments of *Textularia perforata* may be confounded with *Rotalia perforata*.

The thirty-nine species of siliceous-shelled Infusoria belong to fourteen genera, and are as follow:—

Actinocyclus *ternarius*, A. **quaternarius*, A. **quinarius*, A. *senarius*, A. *septenarius*, A. *octonarius*, A. *denarius*; Cocconema *Cretæ*; Cornutella *clathrata*; Coscinodiscus *Argus*, C. *centralis*, C. *lineatus*, C. **minor*, C. **Patina*; Denticella *Fragilaria*, D. *tridens*; Dictyocha *Fibula*, D. *Navicula*, D. *polyactis*, D. *speculum*, D. *stella*, D. *triangula*; Eunotia *zebra*; Fragilaria *rhabdosoma*, F. *striolata*?; Gallionella *aurichalca*?, G. *sulcata*; Haliomma *Medusa*, H. *crenatum*; Lithocampe *lineata*, L. *Radicula*, L. *solitaria*; Navicula *africana*, N. *Bacillum*, N. *eurysoma*, N. *ventricosa*, N. *sicula*; Pyxidicula *prisca*; Synedra *ulna*.

The seven species of soft-shelled Infusoria of the flints belong to three genera, and are the following:—Chætophyta *Pyritæ*; Peridinium *pyrophorum*†; Xanthidium *bulbosum*, X. *furcatum*, X. *hirsutum*, X. *ramosum*, X. *tubiferum*.

The five species of siliceous plants belong to two genera, namely, Spongia (*Tethya*?) *aciculosa*, S. *cancellata*, S. **Cribrum*, S. *binodis*; Spongilla (*Tethya*?) *lacustris*‡.

Of these principal forms the before-mentioned rocks partake in the proportions as stated below: namely,

	Species of Calcareous Polythalamia.	Species of Infusoria.		Species of Siliceous Plants.
		Siliceous, in Chalk.	Soft-shelled in Flints.	
The *Chalk* of				
Puszkary contains	6			
Rügen	7	1		
Jütland	6			
Gravesend	6	3	5	
Brighton	7	1	4	
Meudon	9	.....	2	
Cattolica	9			
The *Chalk Marl* of		Siliceous Infusoria.		
Caltasinetta	7	27	......	4
Oran	2	18	......	1
Zante	5	8	......	2
Greece	3	9	......	1
The *Compact Chalk* of				
Egypt	8			
Arabia	6			
The *Nummulite Limestone* of				
The Pyramids of Geza ...	6	Containing 4 species of Nummulite, the largest of which is one inch in diameter.		

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† *Peridinium delitiense* has hitherto been found only in flint pebbles near Delitzsch, yet accompanied with forms that are common in the flints of the chalk.

‡ In the preceding lists, the species which are marked with an asterisk * are those which most frequently occur, forming the masses of the rocks. The *Rotalia globulosa* occurs in all the localities.

On the Chalk Marl, and its relations to the Chalk and its Flints.

The whole coast of Oran in Africa appears to belong to the chalk formation, composing the plain east of the town, and extending thence to the Atlas. The marl brought from thence as tertiary by M. Rozet in great quantities I had an opportunity of examining in Paris, and I found not only Polirschiefer and an Infusoria conglomerate, but calcareous animalcules of the same species as occur in the chalk of Poland, Rügen, Denmark, and Paris, and which there mainly contribute to its mass. It thus appeared that the so-called tertiary formation of the coast of Barbary might, without much hazard, be brought into a nearer connexion with the chalk. In his description of this tract, M. Rozet states*, "The tertiary formation is extensively developed in Oran, forming the soil of the large plain on the east of the town, and on the south to the Atlas. It forms also the sea-coast to an extent of 3000 metres between Mers el Kebir and Cape Falcon, and the whole soil of the adjacent plain. The lower bed is a blue marl, like that which we found at Algiers and within the Atlas. It appears destitute of organic remains. The second or upper deposit consists of marly and calcareous beds in alternation, forming a thickness of 30 to 40 metres. In the plain these beds are apparently horizontal, as well as in the elevated plain of the Rammra hill; but in the hills south-west of the town of Kasba they are, on an extent of two hours march, inclined to the north, at an angle sometimes exceeding 30°. The beds of limestone are white and chalk-like, yellowish and coarse granular, usually forming the lower part, succeeded by others alternating with yellow marls, which are often slaty and charged with sand, and between them are found layers of ostreæ and other shells. Among them two beds are distinguished, each one metre in thickness, composed of very white finely-laminated marl, containing numerous well-preserved impressions of fishes, so that in a cubic mass of one foot we seldom fail to find three or four fishes. In these beds of marl thus enclosing the fishes, other organic remains do not appear; but in the calcareous and sandy beds which intervene, occur layers of large oysters mingled with grypheæ. The upper part of this deposit is composed of a calcareous breccia, which is exhibited at the surface in the soil of the whole plain on the south-west of Oran."

This exact description of the position and thickness of the white marl with impressions of fishes, has a reference to the

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* Rozet, *Voyage dans la Régence d'Alger*, Paris, 1833. tome 1. chap. v. pp. 56, 63.

Infusoria conglomerate of Oran, to which I have already adverted. It is probably what formed the Tripel of the earlier periods of Italy. When M. Rozet speaks (at p. 28–30) of the great extent of the tertiary tract near Algiers as similar in its relations to those of Oran, I cannot agree with him. On the contrary, forming my judgment by the organic remains, I consider the desert tract near Algiers as really composed of a tertiary formation, which reposes on chalk. This opinion is founded on my observation, that the tract in Libya, extending from Alexandria to Siwa, is composed of tertiary beds, while from Cairo to Geza the chalk formation occurs, which terminates at the granite of Syene, but is far spread into the Desert. The valley of Siwa appears to form the northern boundary of the chalk in Eastern Libya.

In the South of Italy, at Caltasinetta and its neighbourhood, the relations had been correctly seized by our late friend Frederick Hoffmann, from whose diary I have been favoured with an extract by M. von Dechen. He represents the series of strata which occupy the greater part of Sicily as composed of limestones, sandstones, clays, and marls; the lower members being probably referable to the Jura formation, succeeded by such as clearly belong to the chalk, and many beds of which perfectly resemble the hard chalk of the north-west of Germany (Teutoburger Wald). Among the marls are white chalk-like thinly laminated masses, analogous to Tripel, designated by Hoffmann as *white chalk marl*, and which especially occur in the southern part of the island. The beds of the chalk formation usually dip 20° to 30°, while the strike is nearly constant, from 15° to 45° S. of E. and N. of W., parallel to the south coast. The tertiary beds which succeed the chalk are composed of loose sand, friable sandstone, testaceous breccias, clays and limestones. They cover the chalk unconformably, resting on the truncated edges of the latter. The chalk beds are upon the whole poor in organic remains, and these are seldom distinct; there occur Hippurites, Nummulites, Lenticulites, and in a few places indistinct Ammonites and Belemnites, while the tertiary beds are quite filled with innumerable Mollusks, of which nine-tenths are still living in the Mediterranean. This distinction is so striking that it scarcely required the difference of relative position in order to draw a correct line between the two formations. Even had so circumspect a geologist as Frederick Hoffmann not correctly seized and pronounced with decision on these local relations, the numerous microscopic siliceous Infusoria with calcareous Polythalamia which I have found in the chalk marl would have led to the same conclusion.

If we compare Hoffmann's description of this portion of Sicily with that given by Rozet of the coast near Oran, we cannot avoid recognizing a similarity of relations; and the thinly laminated marly beds with impressions of fishes, between Caltasinetta and Castrogiovanni, which Hoffmann refers with certainty to the chalk formation, correspond to the similar beds which occur near Oran, but which were said to be tertiary. And the parallel is confirmed by the microscopic siliceous Infusoria and calcareous animalcules which I have discovered in both.

The genera and species of the siliceous Infusoria in Sicily are so similar to those of Oran and Zante, that of thirty-six species, four occur in all the three countries, three in Caltasinetta and Zante, seven in Caltasinetta and Oran, while in all of them the *Coscinodiscus Patina* is greatly predominant. Of all these siliceous animals, not a single species has been found in the chalk of the North of Europe, nor even in the flints. On the other hand, the calcareous-shelled animalcules, which in the South of Europe accompany the siliceous animals, comprise about one half of the same species that are found in the North, yet exceeding them in quantity.

From the examination of the organic constituents of the chalk marl we learn the hitherto unknown fact, that numerous swarms of microscopic Infusoria were in existence within the period of the secondary formation of the earth's surface, chiefly belonging to such as possess siliceous cases or shells, and which for the greater part are members of such sections of the Bacillaria family as had previously appeared to be confined to the tertiary or newest formations.

Of the thirty-nine or forty species of siliceous Infusoria occurring in the chalk formation, thirty-four or thirty-five have not hitherto been found in the recent state; but it is remarkable that the remaining five or six species so closely resemble existing species of the present day, that they present no peculiar character by which they could be distinguished from them, and hence the application of new names appeared inadmissible. They are, *Eunotia zebra*, *Fragilaria rhabdosoma*, *F. striolata ?*, *Gallionella aurichalca*, *Navicula ventricosa*, *Synedra ulna**.

In the chalk itself only four out of the thirty-nine or forty

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* The indifference shown to climate by Infusoria, and the peculiarity of their organic development, seem to render it possible that they might be more readily preserved through many catastrophes of the earth than other forms. By the faculty which they possess of spontaneous division, a single individual can, under very favourable circumstances, be multiplied in the course of a few hours to the extent of millions.

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